NASA-CR-171286
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IN-CAT. 29
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FINAL REPORT

Space Processing Workshop

for

NASA Contract NAS8-33542

(NASA-CR-171286) SPACE PROCESSING WORKSHOP Final Report (Alabama Univ., Huntsville.) 12 p CSCL 22A

N87-18678

Unclas
G3/29 43557

[redacted]

Date of general release January 1985

November 1984

FINAL REPORT: SPACE PROCESSING WORKSHOP

The scope of contract NAS8-33542 embraced several aspects of the Materials Processing in Space Programs.

The first activity undertaken was a review of the scientific capabilities of the Fluids Experiment System. This objective was accomplished in part through a workshop held on July 11-12, 1979 in Noojin House at the University of Alabama in Huntsville. A number of consultants from outside the Huntsville area were brought to the workshop. (See Participant List and Workshop Agenda, Appendix A).

On the recommendation of this workshop, UAH made an investigation of gravity driven dynamic effects on electroplating. A literature search was conducted and an electroplating apparatus was constructed for microgravity experiments on the KC-135 air-craft. This equipment was ultimately flown several times and experiments were conducted. The results of these experiments have been documented in several reports. (See Appendix B for a general review).

Another investigation supported in part under this contract addressed chemical reactions induced by energetic oxygen atoms impinging on sample surfaces in the environment of earth orbit. This effort included equipment flown on STS-8. The results of this investigation have been reported at several national meetings on this subject. (See Appendix C for a general review).

Appropriate consultants were brought to Huntsville as required to facilitate the experiments discussed and for other joint scientific investigations related to this project.

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Revised 11 July 1979

FLUIDS EXPERIMENT SYSTEM WORKSHOP
July 11-12, 1979

AGENDA

July 10	12-5 p.m.	Seminar Registration in Hilton Lobby.
	5-7 p.m.	Cocktails in Hilton Hotel, Hospitality Rm. 136.
	7:30 p.m.	Dinner - Hilton Hotel, Monte Sano Room Speaker - R. Naumann - "Overview of Materials Processing in Space"
July 11	8-8:10 a.m.	Vans leave from front of Hilton Hotel for Noojin House.
	8:15 a.m.	Continental breakfast - Noojin House Dining Rm.
	8:40 a.m.	Workshop begins - Upstairs Parlor, Noojin House Announcements and Welcome - J. Hendricks.

SESSION A - GENERAL FLUID DYNAMICS

8:45 a.m.	Introduction by R. Naumann
9:00 a.m.	A1 - S. Gelles, B. Bhet & R. Laub - "Phase Separation in Transparent Miscibility Gap Systems"
9:15 a.m.	A2 - I. Krieger - "Diffusion Coefficient from Rates of Solution of Bubbles"
9:30 a.m.	A3 - L. Lacy, G. Nishioka, and S. Ross
9:45 a.m.	Coffee Break
10:00 a.m.	A5 - J. Mann - "Measurement of Surface Velocity Fields"
10:15 a.m.	A6 - S. Ostrach - "Flows Induced by Surface-Tension Gradients"
10:30 a.m.	A7 - T. Schwartz - "Deployment of Solid Particles on Liquid Droplet Surfaces"
10:45 a.m.	A8 - S. Subramanian and W. Wilcox - "Bubble Migration & Bubble-Bubble Interactions in a Thermal Gradient"
11:00 a.m.	Discussion - Led by R. Naumann
12:15 a.m.	Lunch - Noojin House

SESSION B - CHEMICAL PROCESSES

1:15 p.m.	B1 - G. Kuczynski and C. Alcock - "Ostwald Ripening in Microgravity"
1:30 p.m.	B2 - E. Matijevic and R. Sapieszko
1:45 p.m.	B3 - J. Vanderhoff
2:00 p.m.	Discussion - Led by R. Naumann
2:30 p.m.	Coffee Break

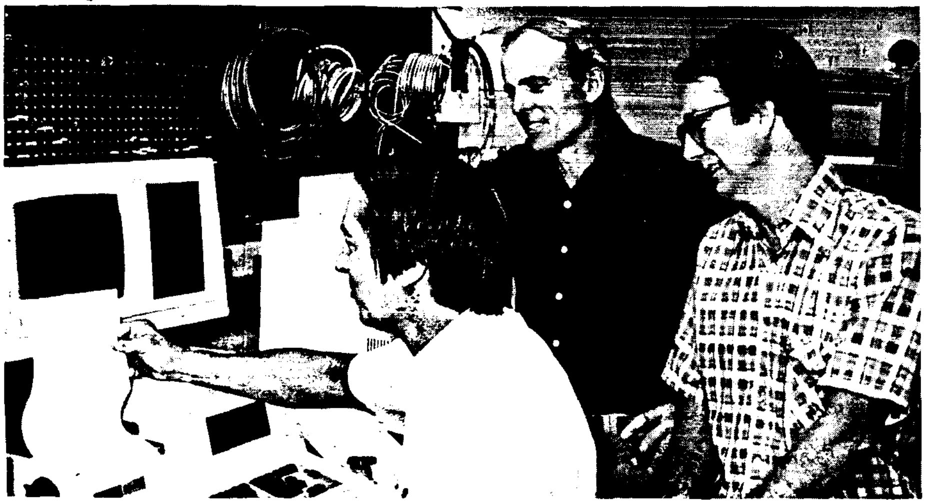
FLUIDS EXPERIMENT SYSTEM WORKSHOP

July 11 (cont.)		SESSION C - BIOLOGICAL PROCESSES
	2:45 p.m.	C1 - D. Brooks
	3:00 p.m.	C2 - G. Cokelet & H. Meiselman - "Some Potential Blood Flow Experiments for Space"
	3:15 p.m.	C3 - S. Flannagan - "Geometrical Considerations in the Separation of Biological Particles by Affinity Partitioning"
	3:30 p.m.	C4 - E. Meehan - "Crystallization of Biological Macromolecules in Reduced Gravity Environment"
	3:45 p.m.	C5 - D. Saville, P. Rhodes, and B. Snyder
	4:00 p.m.	Discussion - Led by R. Naumann
	4:30-5:30 p.m.	Cocktail Hour at the Noojin House
	5:30 p.m.	Bus leaves the Noojin House for the Space and Rocket Center
	6-7 p.m.	Tour Space and Rocket Center - Advise that you see Lunar Odyssey first as it closes at 7:00 p.m.
	7:00 p.m.	Barbecue at Space and Rocket Center
	8-8:30 p.m.	Return to Hilton Inn
July 12	8-8:10 a.m.	Vans leave from Hilton Inn for Noojin House
	8:15 a.m.	Continental Breakfast
	8:40 a.m.	Announcements - J. Hendricks
		SESSION D - CRYSTAL GROWTH EXPERIMENTS
	8:45 a.m.	D1 - A. Authier
	9:00 a.m.	D2 - D. Elwell - "Solution Growth Experiments in Low Gravity"
	9:15 a.m.	D3 - W. Gill - "Anomalous Growth of Single Ice Crystals"
	9:30 a.m.	D4 - M. Glicksman - "Convective Flow During Dendritic Growth"
	9:45 a.m.	Coffee Break
	10:00 a.m.	D5 - M. Good and C. Whitehurst - "Crystal Growing Experiments in Microgravity"
	10:15 a.m.	D6 - J. Hallett - "Influence of Convections on the Growth of Dendrite Crystals in Solutions"
	10:30 a.m.	D7 - F. Rosenberger - "Fluid Dynamics of Vapor Transport"
	10:45 a.m.	D8 - W. White - "Crystal Growth from Low Temperature Fluxes"

FLUIDS EXPERIMENT SYSTEM WORKSHOP

July 12 (cont.)	11:00 a.m.	Discussion - Led by J. Carruthers
	12:00 a.m.	Introduction to holography exhibit - W. Witherow
	12:15 p.m.	Lunch at the Noojin House
	1:15 p.m.	Talk by J. Carruthers - "NASA Research Opportunities"
	2:00 p.m.	Presentation on the FES facility - J. Kropp - TRW
	2:30 p.m.	Discussion of FES facility
	3:30 p.m.	Adjourn

NOTE: From 12:30 to 4:00 p.m. a holography demonstration will be available.



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Chemistry researchers Drs. Samuel McManus, Clyde Riley and Milton Harris share an interest in each other's investigations. Not shown here is Dr. Dwain Coble, who worked with Dr. Riley on the study of electrodeposition in low gravity.

ELECTRODEPOSITION STUDIES IN LOW GRAVITY

Clyde Riley and H. Dwain Coble

Gravity has a significant influence on electromechanical processes. Of particular importance is the effect on electrodeposition. Due to the magnitude of commercial activity involving electrodeposition preparations it is a logical candidate for studying the effects of reduced gravity. We have directed our work toward understanding gravity's role in simple metal electrodeposition (electroplating) and codeposition. In the latter, particles of a neutral material (non-ionic) such as a ceramic, added to the metal plating solution in suspended form, are trapped in the metal deposit. Codeposits are often used for coatings to maximize wear-resistance and antifriction and antiseizing properties.

In a gravity environment, during electrodeposition density gradients are created which result in convective transport that affects forming and surface preparations. If one were stirring these samples, natural convection would be masked by the agitation. Similarly, neutral suspensions tend to sediment, especially for dense particles or those with diameters in excess of about 5 μm. Thus, for codepositions, inhomogeneous coatings and reduction in the volume fraction of the occluded neutral occur. Stirring in a gravity environment to retain suspension can improve homogeneity in the codeposition on flat surfaces, but not near edges and containment walls. Stirring also results in a reduction of the volume fraction of the neutral in the deposit since the moving neutrals are more difficult to trap in the building metal layer.

In these simple metal electrodeposition studies we have chosen to work with copper and cobalt deposits. During electrodeposition positive ions migrate toward a negative charged electrode, where they gain electrons and become neutralized in the form of a metal coating. Removal or addition of ions to a solution results in a density gradient and natural convection. This natural flow leads to pulsing of the solution near the electrode surfaces and defects in the coating. Removing gravity would halt this effect.

We have utilized two methods in our studies to eliminate natural convection. One involves reducing gravity in electrodeposition cells to 1/100 of normal or less by placing them on KC-135 aircraft parabolic flight paths. Another method (CA method) involves operating the cells with both electrodes parallel to the earth's surface and the negative electrode on top. Both electrodes must also have depositing (negative electrode) and withdrawing (positive electrode) surfaces with the same dimensions as the cell cavity. This results in a "light" layer of solution being trapped against the negative electrode at the top of the cell (ions were removed to form the deposit) and a "heavy" layer trapped against the positive electrode at the bottom of the cell (ions came into solution). Since nothing can rise or sink, convection cannot take place. In this method gravity is not turned off, but natural convection is obviated.

In our work we have made observations on solution concentration during electrodeposition for both methods of eliminating convection. Surprisingly, although there should be no differences between the methods, laser interferometry measurements indicate significant differences in fluid concentration changes for the cobalt cell between the two methods. Copper shows no experimental difference. Apparently gravity affects cobalt electrodeposition in more ways than just convection.

We can duplicate the effects of gravity on codeposition by using a CA cell with added polystyrene neutral particles. By making the polystyrene balls the same density as the solution, no sedimentation takes place and there is no convection in a CA method. Initial experiments with 11.8 μm particles give homogeneity (particle inclusion uniformity) of less than 10% deviation. Better yet, volume percentage of codeposition seems to be about a factor of two higher than for electrodeposition where stirring is used to maintain the suspension in gravity. We expect experiments with smaller size particles to produce even better results.

The initial goal of these studies is to demonstrate their feasibility for long term weightless experiments in space. The overall goal would be space processing of superior surfaces.

ATOMIC OXYGEN EXPERIMENT ON SPACE SHUTTLE FLIGHT STS-8

J. C. Gregory

An experiment to investigate the effect of the hyperthermal atomic oxygen atmosphere on some sensitive surfaces was flown on Space Shuttle Flight STS-8. The experiment investigated the physical and chemical effects produced at various surfaces and tested some new techniques for studying whether part of the great kinetic energy of the oxygen atoms is converted into chemical energy upon collision with a surface.

The STS-8 Atomic Oxygen Experiment provided the first well oriented, high-dose exposure of solid samples to the orbital atmosphere in which those samples were protected during re-entry and returned for detailed study.

The results of experiments run on a recent space shuttle flight are analyzed by Dr. John Gregory, an associate research professor of chemistry at UAH.

The objectives of the UAH STS-8 exposure are to begin a study of the energy-accommodation mechanism at solid surfaces of hypothermal oxygen atoms using a new experimental approach; to make an estimate of activation energy (if it exists) for the oxidation of various pure carbons, osmium, silver and a polycarbonate plastic; to screen a number of materials for physical and chemical effects, using the most sensitive techniques; to investigate the variation in oxidation kinetics for different carbons; to develop new techniques of hypothermal oxygen dosimetry; to investigate the effect (if any) of solar UV on carbon oxidation rates; and to investigate the effect (if any) of charged species in the ambient beam on carbon oxidation rates.

Although the presence of atomic oxygen at orbital altitudes has been known for many years, its effects were not generally observed for several reasons. Exposed surfaces were often contaminated in flight or altered by re-entry, and in general were not configured for sensitive measurement of small effects. Some effects were noticed, for example, on silver.

With a few exceptions, the effects of the atomic oxygen beam were confined to a thin surface layer of the exposed material in this experiment. The techniques used here are those evolved during the last few decades of surface physics and chemistry research and thin-film technology.

A novel atomic beam/surface-interaction analyzer (the reflectometer) incorporates a beam collimator, target surface, and a reflected beam detector, which is sensitive to reflected atomic oxygen over the angular range $-40°$ to $+90°$ relative to the target normal. The device may be used to study the following processes:

- tangential momentum accommodation
- normal momentum accommodation
- surface recombination efficiency
- surface reaction efficiency.

A test was made on the STS-8 mission for the contribution of positive and negative ions on the overall surface effects produced on hyperthermal oxygen. Identical samples were covered with transparent grids held at +28V, 0V, and −28V respectively. Three specially marked vitreous carbon samples were provided for this test. Since the concentration of positive oxygen species is of the order of 10^{-3} of the neutrals, no difference between the electrically shielded and neutral samples was expected.

Several chemical systems offer particularly interesting study opportunities. Among them are the reactions with osmium, carbon and silver, all of which react strongly with orbital atomic oxygen.

Annual Research Report 1983
The University of Alabama in Huntsville